THE NUMERICAL ANALYSIS OF PROCEDURE FOR OPTIMIZING VERTICAL HANDOVER PERFORMANCE USING A FLUID FLOW MODEL

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ABSTRACT

One challenge of wireless networks integration is to provide ubiquitous wireless access abilities seamless handover for mobile communication devices between the different types of technologies such as Global System for Mobile Communication (GSM), Wireless Fidelity (Wi-Fi), Worldwide Interoperability for Microwave Access (WiMAX), Universal Mobile Telecommunications System (UMTS) and Long Term Evolution (LTE). This challenge is important as Mobile Users (MUs) are becoming increasingly demanding for services regardless of the technological complexities associated with it. To fulfill these requirements for seamless Vertical Handover (VHO) two main interworking architectures were proposed by European Telecommunication Standards Institute (ETSI) for integration between the different types of technologies; namely, loose coupling and tight coupling. The paper presents the numerical analysis of a Mobile IPv4 (MIPv4) based loose coupling procedure with Media Independent Handover (MIH) for providing optimized performance in heterogeneous wireless networks. The analysis results prove that the procedure can provide a seamless VHO with low latency and extremely low packet loss ratio.

KEYWORDS: *Vertical Handover (VHO), Media Independent Handover (MIH), Loose Coupling, Latency & Packet Loss*

I. INTRODUCTION

With the advancement of Radio Access Technologies (RATs), mobile communications has been more widespread than ever before. Therefore, the number of users of mobile communication networks has increased rapidly. For example, it has been reported that "today, there are billions of mobile phone subscribers, close to five billion people with access to television and tens of millions of new internet users every year" [1] and there is a growing demand for services over broadband wireless networks due to diversity of services which can't be provided with a single wireless network anywhere anytime [2]. This fact means that heterogeneous environment of wireless systems such as Global System for Mobile Communication (GSM), Wireless Fidelity (Wi-Fi), Worldwide Interoperability for Microwave Access (WiMAX) and Universal Mobile Telecommunications System (UMTS) will coexist providing Mobile Users (MUs) with roaming capability across different networks. One of the challenging issues in Next Generation Wireless Systems (NGWS) is achieving seamless Vertical Handover (VHO) while roaming between these technologies; therefore, telecommunication operators will be required to develop a strategy for interoperability of these different types of existing networks to get the best connection anywhere anytime without interruption of the ongoing sessions. To fulfill these requirements of seamless VHO two main interworking architectures were proposed by European Telecommunication Standards Institute (ETSI), namely; loose coupling and tight coupling for integrating between the different types of technologies. On the other hand, Media Independent Handover (MIH) and IP Multimedia Subsystem (IMS) frameworks were proposed by IEEE Group and 3GPP, respectively to provide seamless VHO between the aforementioned technologies by utilizing these interworking architectures to facilitate and complement their works. This paper presents the numerical analysis of a Mobile IPv4 (MIPv4) based loose coupling procedure with MIH for providing optimized performance in heterogeneous wireless networks. The analysis results prove that the procedure can provide a seamless VHO with low latency and extremely low packet loss ratio.

The rest of the paper is organized as follows: section II describes the VHO management. In section III, related works are presented. In section IV, the procedure is presented. In section V, numerical analysis of the procedure is presented and finally, the conclusion is included in section VI.

II. VERTICAL HANDOVER MANAGEMENT

The process which allows the MUs to continue their ongoing sessions when moving within the same RAT coverage areas or traversing different RATs is named Horizontal Handover (HHO) and VHO, respectively. In the literature most of the research papers have been divided VHO management into three phases; Collecting Information, Decision and Execution [3, 4] as described below.

Handover Collecting Information

In this phase, all required information for VHO decision is gathered, some related to the user preferences (e.g., cost, security), network (e.g., latency, coverage) and terminal (e.g., battery, velocity).

Handover Decision

In this phase, the best RAT based on aforementioned information is selected and the handover execution phase is informed about that.

Handover Execution

In this phase, the active session for the MU will be maintained and continued on the new RAT; after that, resources of old the RAT is eventually released.

III. RELATED WORKS

In [5], the VHO approaches proposed in the literature have been classified into four categories based on MIH and IMS frameworks (MIH based VHO category, IMS based VHO category, MIP under IMS based VHO category and, MIH and IMS combination based VHO category) in order to present their objectives in providing seamless VHO. It has been concluded in [5] that MIH is more flexible and has better performance providing seamless VHO compared with IMS framework; hence, the majority of approaches in the literature have been based on MIH framework. The IEEE Group proposed MIH to provide a seamless VHO between different RATs [6, 7]. The MIH defines two entities: first, Point of Service (PoS) which is responsible for establishing communication between the network and the MU under MIH and second, Point of Attachment (PoA) which is the RAT access point. Also, MIH provides three main services: Media Independent Event Service (MIES), Media Independent Command Service (MICS) and Media Independent Information Service (MIIS) [8] such that MIH relies on the presence of mobility management protocols, such as MIPv4 and MIPv6.

In [9], the VHO approaches proposed in the literature have been classified into two categories based on the mobility management protocols (MIPv4 and MIPv6) for which their performances and characteristics have been presented. It has been concluded in [9] that providing service continuity through MIPv4 category under MIH will allow the operators to diversify their access networks due to the advantages of this category, while MIPv6 category under MIH requires future work improvements in terms of VHO decision criteria, additional entities, complexity, diversity of RATs and evaluation using empirical work real environment.

In [10], the two main interworking architectures: loose coupling and tight coupling have been presented where their purposes, features and challenges have been discussed in terms of efficiency of handover duration, probability of packet loss, mobility management, congestion, complexity, overload, additional modification and additional cost. It has been concluded in [10] that loose coupling provides better performance compared with tight coupling which makes loose coupling the interworking architecture of choice to complement MIH vital role in heterogeneous wireless environment to achieve a seamless VHO in conjunction with applying MIPv4.

IV. THE PROCEDURE

As conclusion from the section above; the loose coupling seems to supersede tight coupling for the majority of the compared characteristics. However, the loose coupling still suffers from handover latency and packet loss during VHO between heterogeneous wireless networks such as Wi-Fi, WiMAX and UMTS [10]. To solve these problems, a procedure of loose coupling which could be applied in conjunction with MIPv4 based MIH is presented in [11], as shown in Fig.1. The Home Agent (HA) is collocated with MIIS [2, 6] whereas Foreign Agents (FAs) are deployed in WLAN Access Gateway (WAG) and Access Service Network Gateway (ASN GW) in the Wi-Fi and WiMAX networks, respectively. The PoS location is inside the access network for each RAT gateway i.e. WAG, ASN GW and Radio Network Controller (RNC) in Wi-Fi, WiMAX and UMTS, respectively. The PoA is located inside Node B, Access Point (AP) and Base Station (BS) for UMTS, Wi-Fi and WiMAX, respectively. Each of existing access networks UMTS, Wi-Fi and WiMAX is independently deployed and the Wi-Fi and WiMAX data do not pass through 3GPP core network. The MIIS is responsible for collecting all information required to identify the need for handover and provide them to MUs for selecting target RAT (e.g., availability of PoA, locations of PoA, capabilities of PoA, cost, etc). After selecting the target RAT (WiMAX of PoA) and its resources availability have been checked by Admission Control (AC) at WiMAX PoS, the new data packets which are is sent by Correspondent Node server (CN) will be early buffered by MIIS/HA server. This will guarantee the following: (a) minimize time interval in which the MU does not receive any packets as a result of handover (latency) and (b) minimize packet loss to be approximately zero due to the MU makes use of data buffering period in MIIS/HA server to receive target RAT by Wi-Fi PoA and start its authentication with WiMAX PoA to obtain Care of Address (CoA). After that, Update/Acknowledge binding message notifies HA about the new CoA to start sending the buffered data and continuing the session within target RAT. Finally, the resources are released by MIH after completion of sending the buffered data.

V. NUMERICAL ANALYSIS

In this analysis, the handover from WiMAX to Wi-Fi network based on MIPv4 is considered. To analyze the performance of the procedure, fluid flow model is applied in this paper. A hexagonal model is supposed as shown in Fig.2 where the $N(R)$ is number of all cells is given by (1) [12]. The cell boundary crossing rate R_C (mobiles/s) is given by (2), ρ is the mobile density (mobiles/m^2), v is the moving velocity (m/s) and L is the cell perimeter (m) [12, 13].

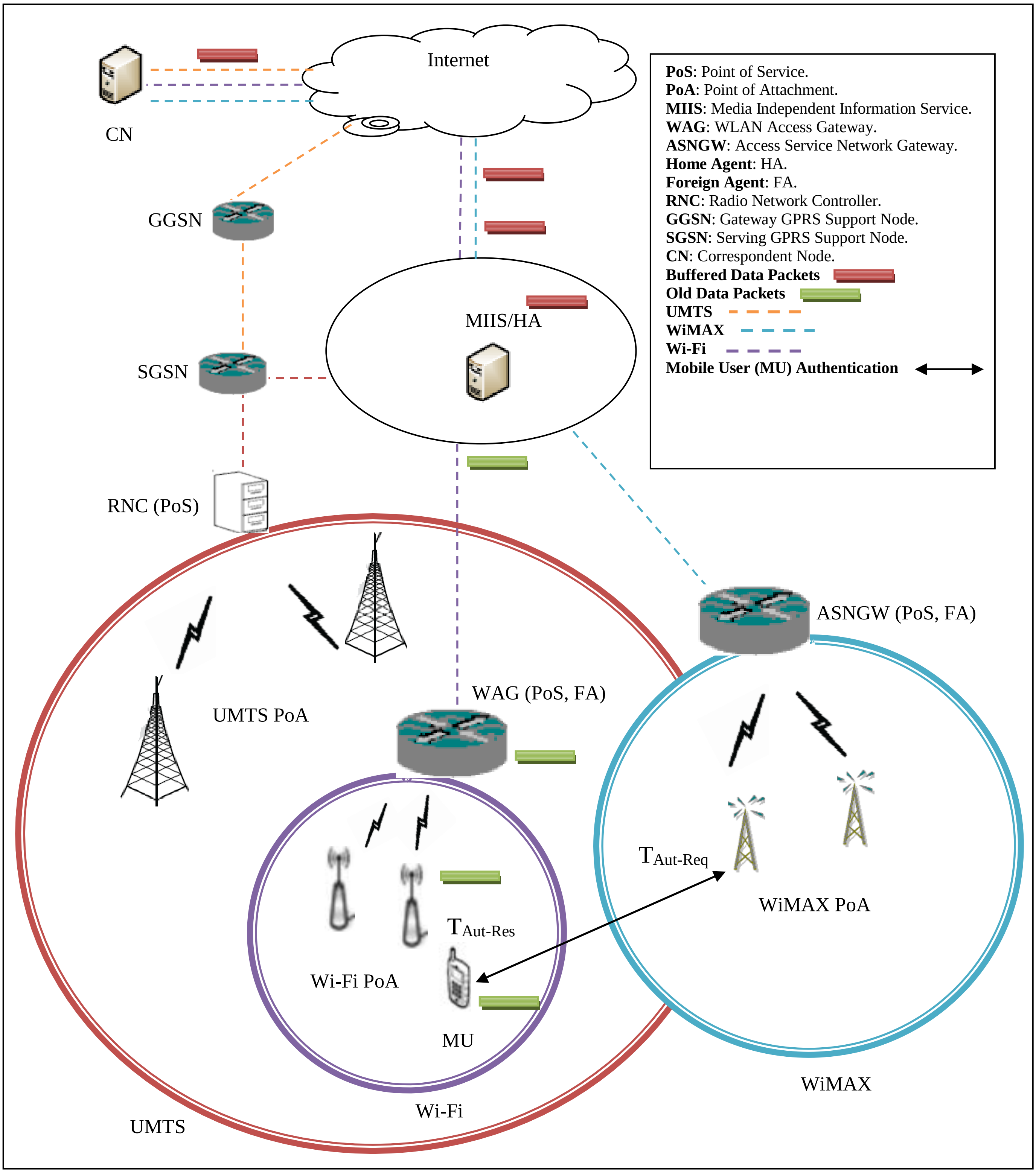

Figure 1. The procedure of loose coupling based on MIPv4 with MIH [11]

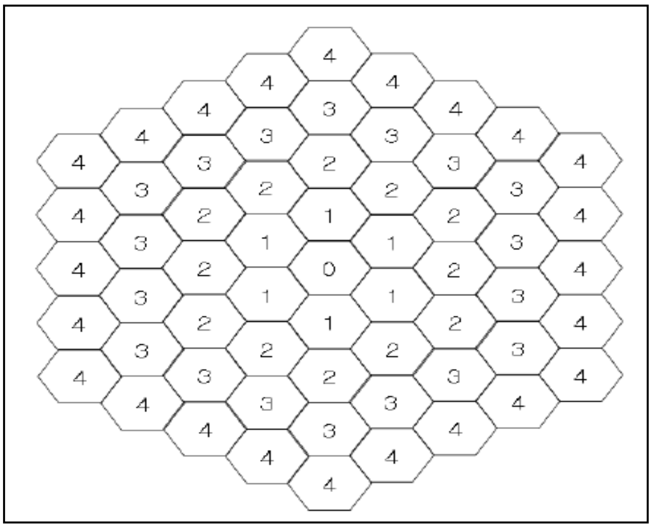

Figure 2. Suggestion of mobility model [12]

$$N(R) = \sum_{r=1}^{R}(6r + 1) = 3R(R + 1) + 1 \quad (1)$$

$$R_C = \frac{\rho v L_c}{\pi} \quad (2)$$

The paging area boundary crossing rate R_d is:

$$R_d = \frac{\rho v L(R)}{\pi} \quad (3)$$

And Formula 4 means equation for *L(R)*.

$$L(R) = 6 * (2R + 1) * \frac{L_c}{6}(R \geq 1) \quad (4)$$

5.1 Evaluation of the Procedure

The latency is the main cause of packet losses during handover so it needs to be minimized [15, 16 and 17]. As a result of concurrent notification which informs both of MIIS/HA server to start buffering and Wi-Fi PoS to pass selected target RAT to Wi-Fi PoA, the Wi-Fi PoA sends target RAT to the MU for handover. The MU makes use of the data buffering period in MIIS/HA server to start/end authentication messages with WiMAX PoA at $T_{Aut\text{-}Req}$ (Time of authentication request) and $T_{Aut\text{-}Res}$ (Time of authentication respond) to obtain CoA whereas the old data packets are still sent to MU at old IP address. After that, Update/Acknowledge binding message notifies HA about the new CoA to start sending the buffered data and continuing the session within target RAT (WiMAX PoA). This will achieve the following: (a) minimize time interval in which the MU does not receive any packets as a result of handover (latency) and (b) minimize packet loss to be approximately zero.

In this evaluation, T_{UB} and T_{BA} are two parameters defined to calculate numerical analysis of VHO performance (latency and packet loss). Where T_{UB} is latency of binding update and T_{BA} is latency of binding acknowledgment. Total handover latency time that is applied to fluid flow model *"T"* is given by (5) where *N (A)* is area of cells [12].

$$T = \frac{qN(A)}{N(R)Rc - Rd} THO \qquad (5)$$

Equation (6) shows percentage of packet loss while MU receiving downlink real time IP packets [14] taking into account total handover latency (T) from equation (5). It does not depend on the downlink bit rate or the length of the session [14]. Rather, it depends on cell residence time and the time taken to discover and complete a mobile IP registration where *Pkt loss* is percentage of packet loss, T_{agt_adv} is mean period at which AP/BS sends agent advertisement over the wireless link and t_{cell} is value of cell residence time [14].

$$Pkt\_loss = (1/2 * T_{agt\_adv} + T) / t_{cell} \qquad (6)$$

5.2 Analysis Results of the Procedure

Based on the analysis above, the evaluation performance of the procedure in terms of handover latency and packet loss is presented. Parameters values used in this evaluation are adopted from [14, 18, 19 and 20].

The result of equation (5) is shown in Fig.3. It illustrates the procedure with minimum latency of ($1.6x10^{-3}$ sec) at velocity 28.9 km^2/h and maximum latency of ($4.9x10^{-2}$ sec) at velocity 1 km^2/h. The result of equation (6) is shown in Fig.4. It illustrates the procedure with minimum packet loss ratio of ($5x10^{-2}$) at velocity 28.9 km^2/h and maximum packet loss ratio of ($5.4x10^{-2}$) at velocity 1 km^2/h. The latency is the main cause of packet losses during handover; therefore, the results obtained in this numerical analysis show that the packet loss ratio improves as long as the latency reduced.

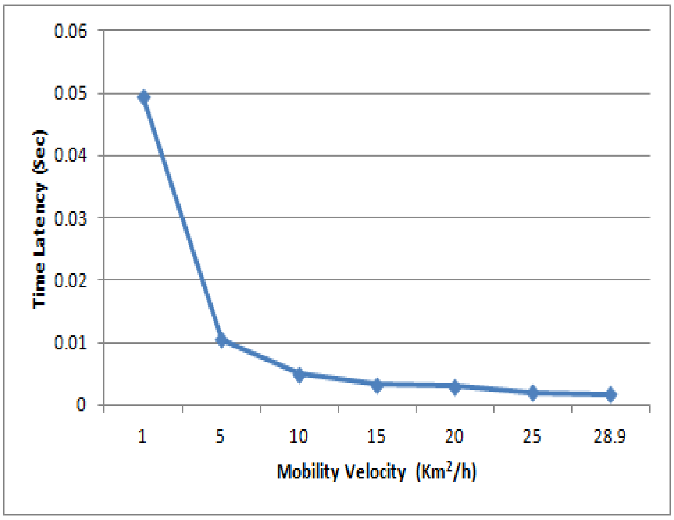

Figure 3. MIPv4 based procedure with MIH (Latency)

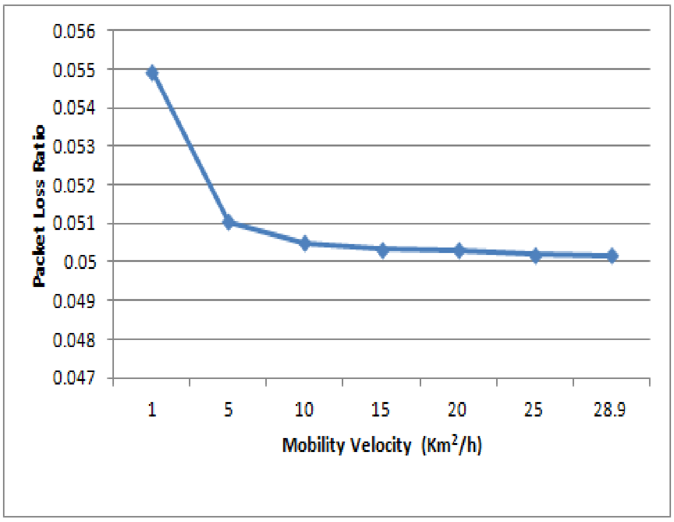

Figure 4. MIPv4 based procedure with MIH
(Packet loss)

VI. CONCLUSION

This paper has presented the numerical analysis of a MIPv4 based loose coupling procedure with MIH for providing optimized performance in heterogeneous wireless networks. Results of the procedure have shown that it could provide seamless VHO with minimal latency and low packet loss ratio. In the future work, it would be preferable to consider a much more sophisticated scenarios and parameters in order to obtain new results about system performance.

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